HEAVY LIFTING DESIGN USING STAAD PRO

LEE SAN YIN

CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JANUARY 2009

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Dissertation submitted in partial fulfillment of
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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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Approved by,

(AP Dr Nasir Shafiq)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources and persons.

LEE SAN YIN

ABSTRACT

This report marks the commencement of the Final Year Project titled Heavy Lifting Design Using STAAD Pro. This project is a study of the factors affecting design of heavy lifting, parameters and limitations revolving around the design of heavy lifting using steel analysis software – STAAD Pro. This project is conducted to study on factors to be considered in design, how heavy lifting of a structure is manifested and analyzed in suitable software and what design solutions can be employed to produce an effective design, both safely and economically.

ACKNOWLEDGEMENT

I would like express my deepest gratitude to the various people that have given me help and support for the completion for my Final Year Report.

First and foremost, I would like to convey my sincere gratitude to my Supervisor – Associate Professor Dr. Nasir Shafiq for his commitment and willingness to supervise me this FYP.

Million thanks to Structural Engineer, Miss Syazwani Zainal for providing the case study's information.

Finally, I would like to thank everyone who has helped me directly and indirectly throughout my Final Year Project.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Heavy lifting is generally lifting a package/cargo/structure which generally requires additional equipment (crane) and or methods to lift it. Heavy Lifting is dangerous yet a necessity in various fields of work. For instance in civil and structural field, heavy lifting is unavoidable in the construction and installation of building structures, bridges, tunnels sewage treatment plants and etc. Heavy lifting also plays an important role in onshore and offshore structures fabrication and installation as well. For instance:

Figure 1.1 Heavy Lifting Works at Petronas Refinery Kedah

Various structural analysis softwares can be used in lifting design. There are StruCalc, Visual Analysis, SACS and etc. For this project, STAAD Pro generated by Bentley Systems is used for simulation and design for lifting. STAAD Pro is the premier FEM analysis and design tool for any type of project including towers, culverts, plants, bridges, stadiums, and marine structures for FEM has long been recognized and accepted as one of the most effective techniques for analyzing structural members and for particular cases under arbitrary/separate loading and boundary conditions. It is a user-friendly Structural Analysis and Design Software that allow different types of loading, complete with various codes such as AASHTO, ASCE 52, IBC, US aluminum code, BS5950:2000, AISC and etc. BS5950:2000 and AISC are the two important codes that will be followed in the design of lifting for this project.

1.2 Problem Statement

Although heavy lifting is a common sight especially in the construction and installation's scope of work, it is considered one of the high risk operations that will lead to fatality. For instance, review taken from HSE's Offshore Division (OSD)'s Key Programme 2 (KP2), it is clearly shown that lifting operations have significant contribution to fatalities and major injuries.

Deck and drilling - Lift related			
	Fatal	Major	Over 3 day
2001/02	1	5	5
2002/03	0	4	4
2003/04	0	5	6
2004/05	0	5	6
2005/06	1	8	12
2006/07	0	6	18

Figure 1.2 Injuries and Fatalities Data Due To Lifting

This statement can further be supported by the news published at 11.02.2008 on Petroleum Safety Authority Norway. The article that is titled 'Multi-national crane/lift audits in the North Sea basin' highlighted:

'If major accidents such a Piper Alpha and Alexander Kielland are excluded, almost 50 per cent of all fatal incidents in the offshore petroleum activities are related to crane and lifting operations/materials handling.'

1.3 Objectives and Scope of Study

1.3.1 Objectives

The objectives of this project is to

- To study the main issues/challenges in heavy lifting and evaluate the causes for dangerous occurrence.
- To simulate the various lifting configuration with different type of sling material in precise FEM using STAAD Pro and validate the results with the field studies.

1.3.2 Scope of Study

In general, the scope of studies of this project encompass

- STAAD Pro.
    - Model Generation
    - Analysis
    - Design to visualization
    - Result Verification
- Factors to be considered in heavy lifting design
- Safe Checking

CHAPTER 2

LITERATURE REVIEW

2.1 Lifting Dangerous Occurrences

2.1.1 Factors of lifting dangerous occurrences

According to reports taken from HSE's Offshore Division (OSD)'s Key Programme 2 (KP2), there are at least 7 factors that contribute to lifting dangerous occurrences. A similar pattern is thought to exist worldwide.

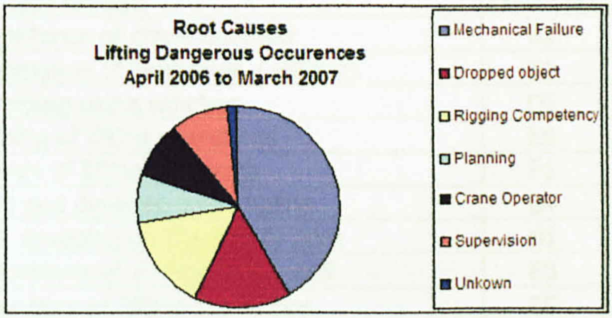


Figure 2.1 Root Causes of Lifting Dangerous Occurrences April 2006 to March 2007

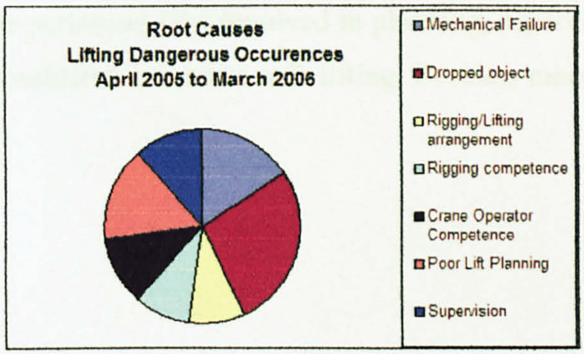


Figure 2.2 Root Causes of Lifting Dangerous Occurrences April 2005 to March 2006

Mechanical failure, incompetence of personnel engaged and poor planning are the causes to lifting dangerous occurrences. Mechanical failure, most of the time is crane-related. Construction Safety Association of Ontario (1696-1994) reviews that an average of 10% of construction fatalities were related to crane and rigging from 1979-1994 and New South Wales Construction industry (AFCC, 1987) also indicates that approximately 12% of fatalities were crane-related.

2.1.2 Main issues to avoid lifting dangerous occurrences

In order to produce safe lifting, certain issues should be prioritized. Referring to 'International Regulators' Forum – Generic report on offshore lifting and mechanical handling issues' from Canada-Nova Scotia Offshore Petroleum Board, the ten lifting issues should be prioritized are shown in Table 2.1.

Table 2.1 Top Ten IRF Lifting Issues

TOP TEN ISSUES	ISSUE No	RANK
Competence of crane operator	E2	22
Competence of banksmen / slingers	E1	21
Man riding using winches	D3	20
Planning of lifting operations	E6	19
Analysis of lifting accidents	F1	19
Static and dynamic crane rating	B4	18
Hook snagging on the supply boat	B1	17
Competence of maintenance staff	E3	17
Supervision of lifting operations	E5	17
Inadequate maintenance	E7	17

The competence of the personnel who involved in planning, supervising and undertaking lifting operations is considered crucial to safe lifting. Besides, maintenance is also a key area of concern.

2.2 Equipment used during lifting

Aside from competent personnel and good lifting operation planning, lifting operations also involves machineries and accessories that have the load capacity to perform lifting.

2.2.1 Crane

Generally, a crane is a lifting tool equipped with a winder, wire ropes or chains and sheaves that can be used both to lift and lower object of significant weights. There are various types of cranes with ranging load capacities and boom length that can be operated on land or on sea. Each crane has its own crane table that specifies the dimensions of the crane, the lifting capacity at different angle with different elevation and boom length. Generally, a shorter boom length and angle closer to 90% will give higher lifting capacity. A crane does not carry loads of its maximum capacity. Normally, it only carries up to 75% of its maximum capacity. Below portrays different types of cranes that are more commonly use in construction and installation.

2.2.1.1 Mobile Crane

A mobile crane is a lifting device traveling over rubber-tired wheels and usually has smaller load capacity. Unlike crawler crane, mobile crane is immobile when lifting is in progress.

Figure 2.3 Mobile Crane

2.2.1.2 Crawler Crane

A crawler crane is a lifting device mounted on an undercarriage with a set of tracks namely crawlers that provide for the stability and mobility of the crane.

Figure 2.4 Crawler Crane

2.2.1.3 Tower Crane

A tower crane is lifting device that is normally fixed to the ground or 'jacked up' and supported by the structure as the structure is being built. It is a common sight during construction of high rise building.

Figure 2.5 Tower Crane

2.2.1.4 Gantry Crane

A gantry crane is a lifting device that has a hoist in a trolley which runs horizontally along gantry rails, usually fitted underneath a beam spanning between uprights which themselves have wheels so that the whole crane can move at right angles to the direction of the gantry rails.

Figure 2.6 Gantry Crane

2.2.1.5 Overhead Crane

An overhead crane is a lifting device with a single or multiple girder movable bridge, carrying a movable trolley or fixed hoisting mechanism, and traveling on an overhead fixed runway structure.

Figure 2.7 Overhead Crane

2.2.1.6 Floating Crane

A floating crane is a lifting device that is mounted on barges or pontoons, which can be towed or is self propelled and are used mainly in bridge building and port construction.

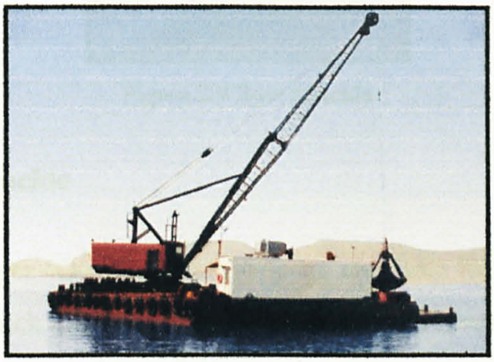


Figure 2.8 Floating Crane

2.2.2 Shackle

A shackle is a U-shaped piece of metal secured with a pin or bolt across the opening, or a hinged metal loop secured with a quick-release locking pin mechanism. They are used as a connecting link in all manner of rigging systems, from boats and ships to industrial crane rigging. Shackles can be used to link between slings to produce longer length. Shackle, like crane, have its own table listing its properties such as inner depth, pin diameter for different load capacity. Two types of commonly used shackles are:

2.2.2.1 Pin shackle

A *pin shackle* is closed with a clevis pin. Pin shackles used to be the most common shackle used aboard boats, primarily used above the deck. Pin shackles can be inconvenient to work with at times because they are secured using something else, usually a cotter pin or seizing wire.

Figure 2.9 Bow Shackle

2.2.2.2 Bow shackle

Bow shackle, with a larger 'O' shape to the loop, can take loads from many directions without developing as much side load. However, the larger shape to the loop does reduce its overall strength.

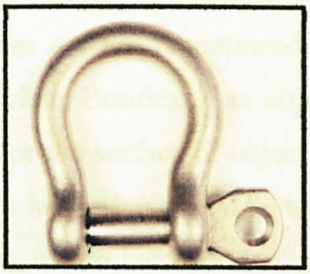
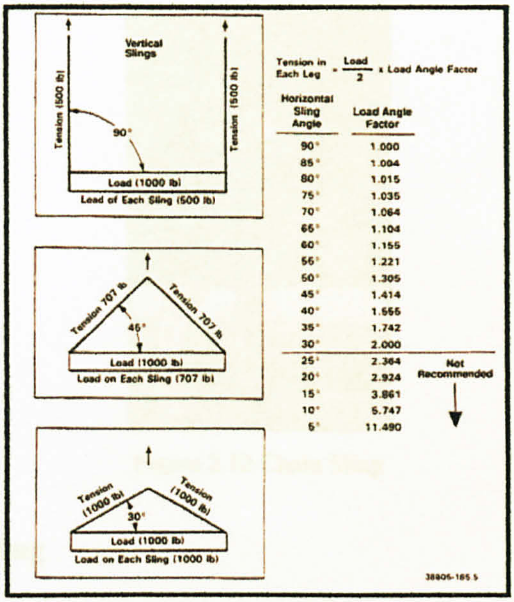


Figure 2.10 Bow Shackle

2.2.3 Lifting sling

A *lifting sling* is a looped wire rope, metal mesh, synthetic fabrics or chain for supporting, cradling, or hoisting something. Sling will be fit to other steel fittings such as connectors, shackles, hooks, couplers and etc. When choosing the type of sling to use, it is important to consider a number of things about the load, which are size, shape and even the temperature as certain types of slings may stretch, melt or break in extreme heat.

Sling orientation is crucial during lifting. The 'sling to load angle' is the angle between the horizontal top of the load and the leg of the sling. The safe capacity of the sling will decrease as the 'sling to load angle' decreases.



Tension in Each Leg = $\frac{\text{Load}}{2}$ x Load Angle Factor

Horizontal Sling Angle	Load Angle Factor	
90°	1.000	
85°	1.004	
80°	1.015	
75°	1.035	
70°	1.064	
65°	1.104	
60°	1.155	
55°	1.221	
50°	1.305	
45°	1.414	
40°	1.555	
35°	1.742	
30°	2.000	
25°	2.364	Not Recommended
20°	2.924	
15°	3.861	
10°	5.747	
5°	11.490	

Figure 2.11 Table of Sling Angle with Load Angle Factor

It is advisable to position the sling in order to obtain at least 70% of the capacity of sling. Thus, angles less than 45 degrees are not recommended and those below 30 degrees should be avoided whenever possible. Besides, if an object has been painted, chain sling will not be chosen as it will deface the surface of object being lifted. In such cases, web sling will be chosen. Normally, a long sling would be used during lifting to double wrap (U-wrap) for the ease of wrapping and to increase its capacity. Below listed two types of slings:

2.2.3.1 Chain Sling

Chain slings are often made of alloy and are normally selected when operating under high temperatures or rugged conditions due to its durability. Other types of sling would abrade or destroy under such conditions. But a reduced load limit is recommended when using chain in temperatures above 425°C (800°F). Chain sling are flexible, durable and long lasting, ductile, easy to inspect, collapsible for convenient storage, and will adhere securely to the contours of a load.

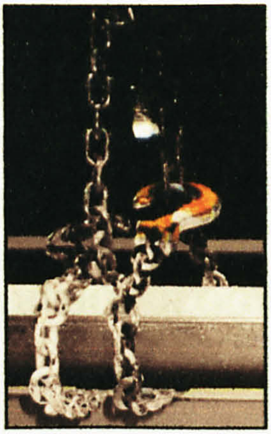


Figure 2.12 Chain Sling

2.2.3.2 Web Sling

Web slings are generally constructed of synthetic web, nylon, or less frequently, polyester material. They are the most flexible sling. Synthetic web slings are easily cut and have poor abrasion resistance when compared with chain and wire rope slings; nylon slings are damaged by acids, but resist caustics and polyester slings are damaged by caustics but resist acids. They are often selected when expensive, highly polished, fragile or delicate loads must be lifted. The softness of the web will not mar, deface or scratch loads, while its flexibility assures a firm, secure grip around the item being lifted.

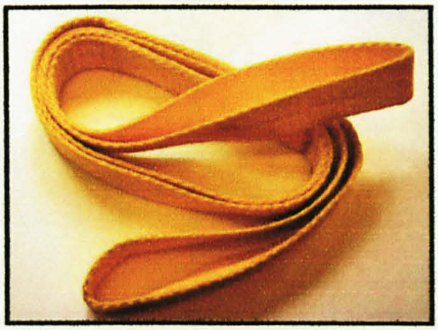
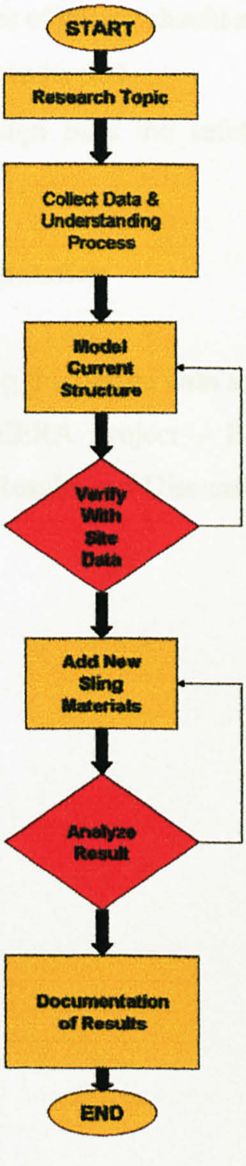


Figure 2.13 Web Sling

CHAPTER 3

METHODOLOGY

3.1 Flow Chart



Note: Gantt Chart is attached as appendix.

3.2 Software

3.2.1 STAAD Pro

For this project, STAAD Pro 2006 is used to conduct lifting analysis and to produce lifting operation design. The actual structure to be lifted is being modeled and simulated using this structural analysis software to:

- estimate the loads to be carried at various location
- determine capacity and types of slings, shackles (if needed), cranes to be used
- determine location of slings to be tied
- ensure that the lifting design pass the safety checking for both British and American Code

3.3 Case Study and Software Stimulation

This study case involves comparing the design data using software simulation with field data on a lifting operation of HEERA Project – B134-A Top Panel. The details of analysis are shown in Chapter 4 – Results and Discussion.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Data Gathering & Analysis

4.1.1 Case Study

4.1.1.1 Modeling

Petronas's Project – J4 Boat Landing is used as a test item for software simulation.

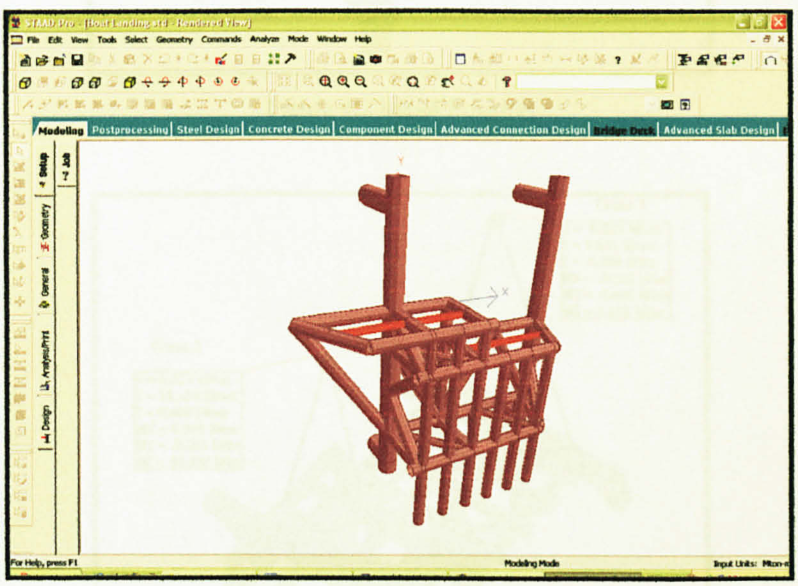


Figure 4.1 Modeling J4 Boat Landing in STAAD Pro

J4 boat landing was fabricated face-down, to provide a flat surface for temporary foundation to prop up. Boat landing was planned to install offshore, but trial fit on the jacket needs to be carried out at the fabrication yard first to ensure the connection points are fit.

Trial fit of this structure requires both lifting and upending. Lifting and upending design is being analyzed using STAAD Pro prior to the actual lifting and upending process. Two cranes are needed for the initial lifting and upending whereas only one crane will be used during the final lifting.

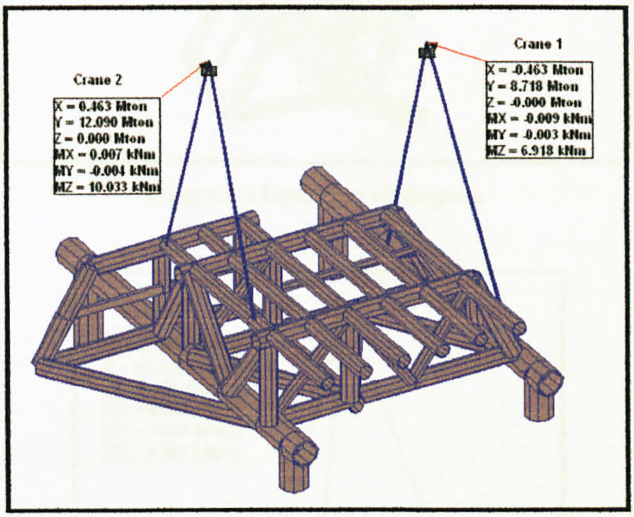


Figure 4.2 Initial Position

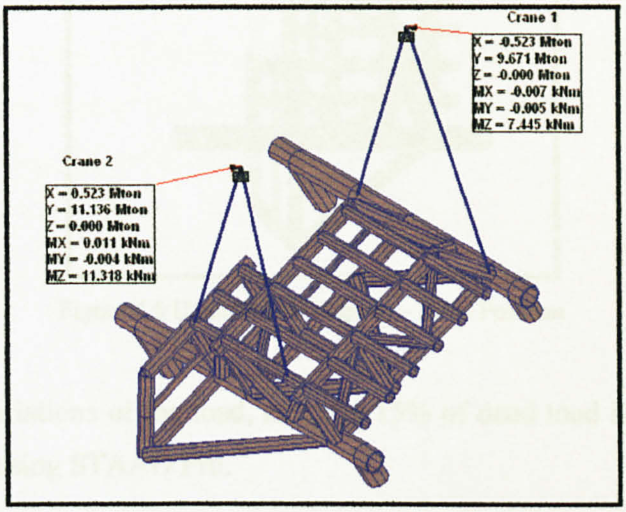


Figure 4.3 Upending 30 degrees

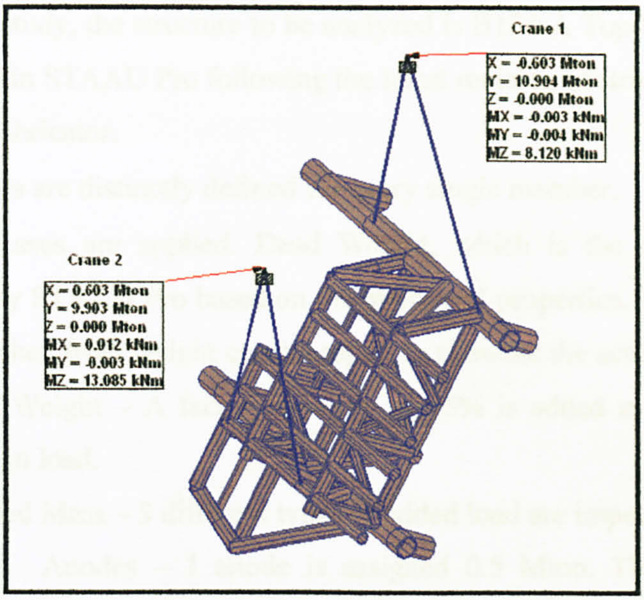


Figure 4.4 Upending 60 degrees

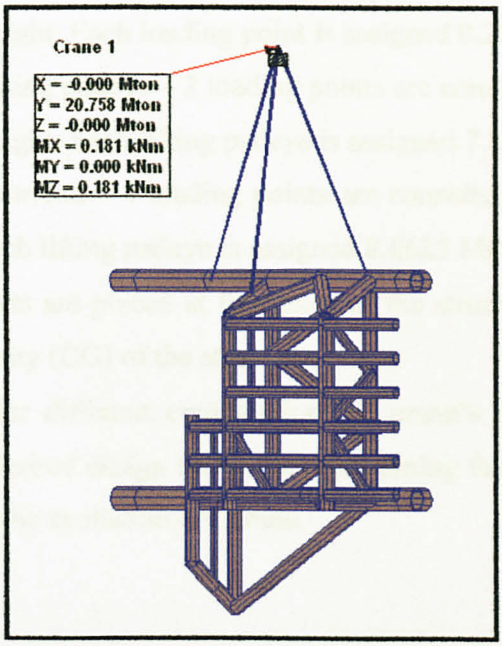


Figure 4.5 Upending 90 degrees – Final Position

To encounter the variations of the load, an extra 15% of dead load is taken into account during the analysis using STAAD Pro.

Note: J4 Boat Landing's structure drawing will be attached in appendix.

In the second case study, the structure to be analyzed is B134-A Top Panel. B134-A Top Panel was modeled in STAAD Pro following the latest revision of structure drawing from offshore structure fabricator.

- The materials are distinctly defined for every single member.
- Two load cases are applied. Dead Weight, which is the self weight is self calculated by STAAD Pro based on the members' properties. The imposed loads' values are taken from weight control report to simulate the actual weight.
    - Self Weight – A factor of safety of 15% is added to the self weight as design load.
    - Added Mass – 3 different types of added load are imposed.
        - Anodes – 1 anode is assigned 0.5 Mton. There are 35 anodes welded at the top panel. Anode is transferring the weight on the two ends, thus yield 70 loading points are considered for anodes' weight. Each loading point is assigned 0.225 Mton.
        - Lifting padeye – 2 loading points are considered for lifting padeyes' weight. Each lifting padeye is assigned 7.875 Mton.
        - Trunnion – 4 loading points are considered for trunnions' weight. Each lifting padeye is assigned 8.6625 Mton.
- Four fixed supports are placed at four ends of the structure to obtain the weight and center of gravity (CG) of the structure.
- Trial and error for different combinations of crane's position is conducted to obtain the most desired design under the constraining factors such as the capacity of crane and also the availability of crane.

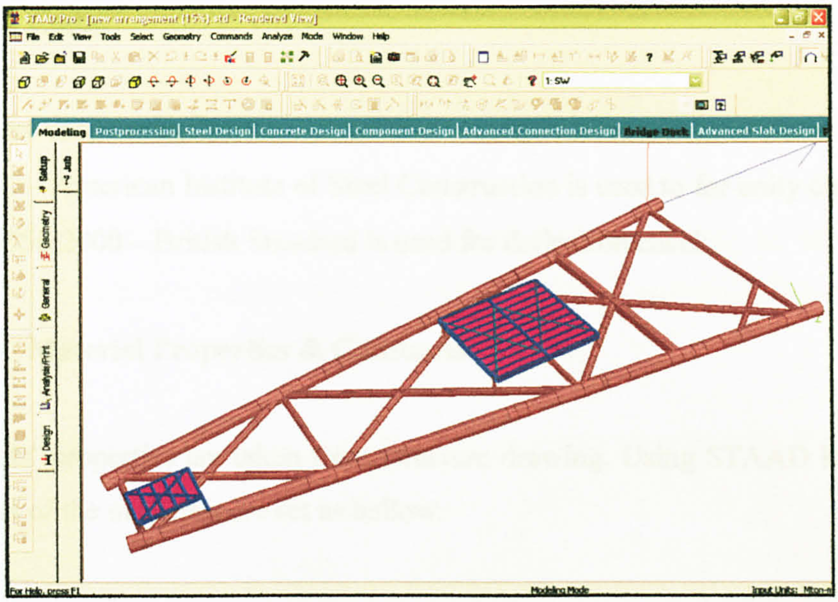


Figure 4.6 Modeling B134-A Top Panel in STAAD Pro

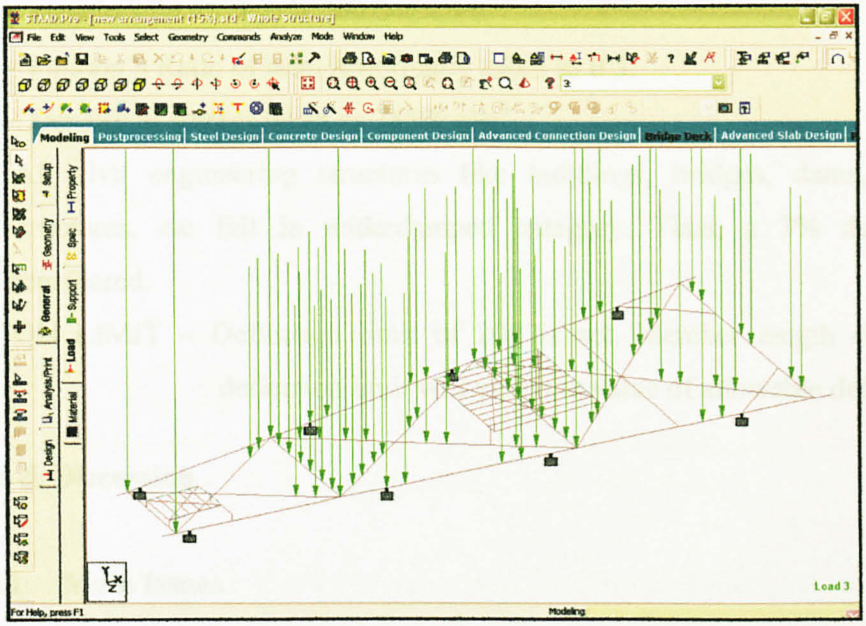


Figure 4.7 Loading of B134-A Top Panel in STAAD Pro

B134-A Top Panel was fabricated facing up. No upending is needed.

Note: The structure drawing of B134-A Top Panel is not disclosed because permission to disclose the structure drawing owned by Punj Lloyd is not granted.

4.1.1.2 Codes

Two codes are used for analysis.

- AISC – American Institute of Steel Construction is used to for unity check.
- BS5950:2000 – British Standard is used for deflection check.

4.1.1.3 Material Properties & Constants

The materials' properties are taken from structure drawing. Using STAAD Pro, some of the constants of the materials are set as bellow:

ISOTROPIC STEEL

E - Young modulus, E of steel falls between 190 GPa and 210 GPa. The default value for isotropic steel in STAAD Pro is 209.042 GPa.

POISSON – Poisson's Ratio of steel is normally taken as 0.3.

DENSITY – Density of steel is taken as $7850 kg/m^3$.

DAMP – All civil engineering structures like buildings, bridges, dams, offshore structures, etc fall in underdamped category. Thus, a 3% damping is considered.

DEFLECTION LIMIT – Deflection limit of 200 is set. Member length divided by deflection limit will yield the value of allowable deflection.

4.2 Results & Discussion

4.2.1 Main Issues

Main issues to be considered in lifting design are

- Weight
- Center of Gravity
- Clearance
- Crane's direction

- Availability of resources (crane)

4.2.1.1 Weight

Different Factor of Safety (FOS), from purely self weight (% FOS) to 20% FOS was imposed to the structure's weight to obtain different design weight. B134-A is used to ease the explanation. The results are tabulated in Table 4.1.

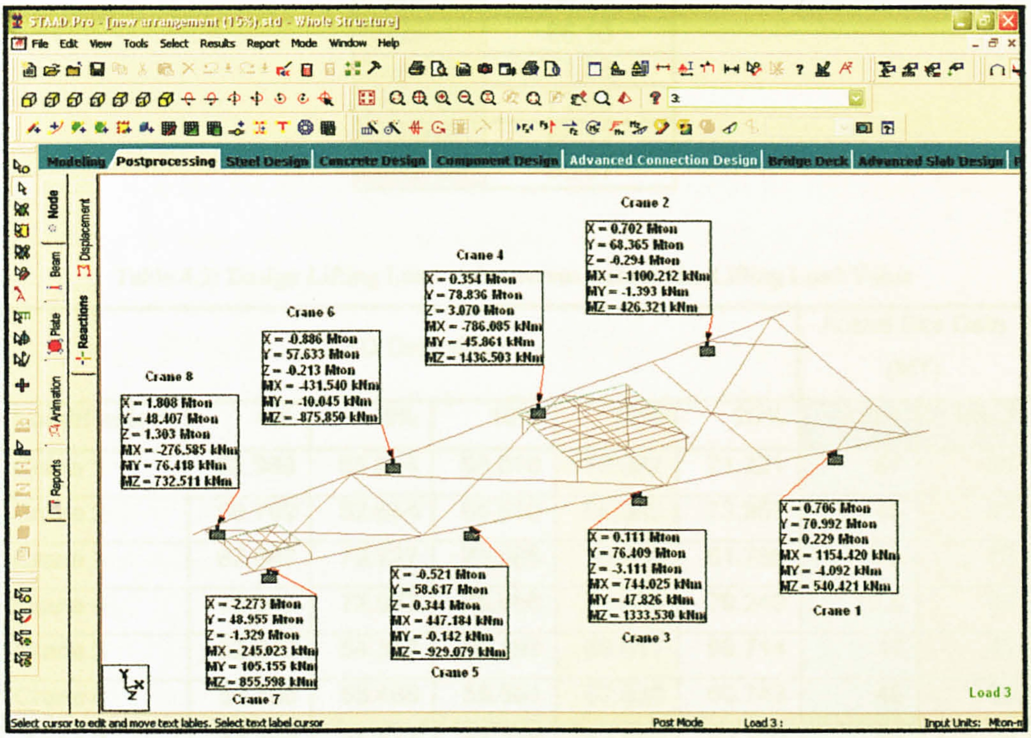


Figure 4.8 Design Lifting Load of 15% Extra Self Weight

In this analysis, no environmental loads are applied as lifting and upending process as in actual cases, lifting of such structures will not be conducted in a bad weather such as heavy rain or wind. The cranes' paths are assumed to be level as during the actual lifting, uneven ground would be leveled. Thus lifting loads are assumed to be constants in the lifting design during the shifting of the structure in its final position from the fabrication area to its final destination although in actual lifting, there is will a variation in loads.

After the loads' reaction is generated, to decide on the crane capacity, a FOS of at least 1.2 is required. Thus, in the actual heavy lifting design procedure, the proposed cranes' capacity needed is shown as below:

Table 4.1: Crane Capacity

Crane	Capacity (MT)
Crane 1	85.47
Crane 2	88.76
Crane 3	98.12
Crane 4	95.10
Crane 5	71.66
Crane 6	72.89
Crane 7	60.12
Crane 8	60.81

Table 4.2: Design Lifting Load Value versus Actual Site Lifting Load Value

STAAD Data (MT)						Actual Site Data (MT)	
Load/Factor'	0%	5%	10%	15%	20%	Set 1	Set 2
Crane 1	62.069	65.044	68.018	70.992	71.221	57	68
Crane 2	59.799	62.654	65.510	68.365	73.967	45	45
Crane 3	67.887	70.727	73.568	76.409	81.766	78	79
Crane 4	70.047	72.977	75.906	78.836	79.249	79.5	80
Crane 5	52.243	54.368	56.493	58.617	59.714	47	42
Crane 6	51.388	53.469	55.551	57.633	60.742	45	33
Crane 7	43.798	45.517	47.236	48.955	50.102	22	20
Crane 8	43.325	45.019	46.713	48.407	50.674	32	30
Sum	450.556	469.775	488.995	508.214	527.435	405.5	397
NOTE:							
*Load = Load Lifted by Crane							
*Factor = Additional % of Factor Added to Self Weight							

Table 4.2 shows a comparison between the loads generated in STAAD Pro. and site data which is the actual loading reporting by the cranes' operator. 2 sets of actual site data are

taken to make comparison. Set 1 was taken when the top panel is just lifted from the temporary support while set 2 was taken when the top panel is moved half way to the jacket assembly area. By comparing actual site data set 1 and set 2 with design load of extra 15% of structure's weight, it is shown that an average FOS of 25% to 28% is obtained. Thus, for this case study, a FOS of 15% of the self weight is sufficient to give a safe design.

4.2.1.2 Center of Gravity (CG)

CG is crucial in deciding the position of the cranes.

- Lifting points that are closer to CG will yield bigger lifting load value.
- Lifting points that are evenly spaced apart from CG will give the same lifting load value (for structure that is symmetrical in one or both X and Y axis).

Thus in design, lifting points of cranes are placed approximately at equal distance away from the CG so that the load lifted by the opposite cranes are similar. Large variations of lifting load carried by the opposite crane will lead to lifting failure because the lifting load varies when the top panel is shifted slowly towards the jacket assembly area. This happened due minor swaying movement of the structure, minor wind load and uneven ground.

CG can be obtained from STAAD Pro after complete modeling, loading and support placing. Run analysis and CG is shown in STAAD output. An example is shown below:

CENTER OF GRAVITY OF THE STRUCTURE IS LOCATED AT: (MMS UNIT)

X =-31758.02 Y = 114.00 Z = 13261.97

TOTAL SELF WEIGHT = 384.405 (MTON UNIT)

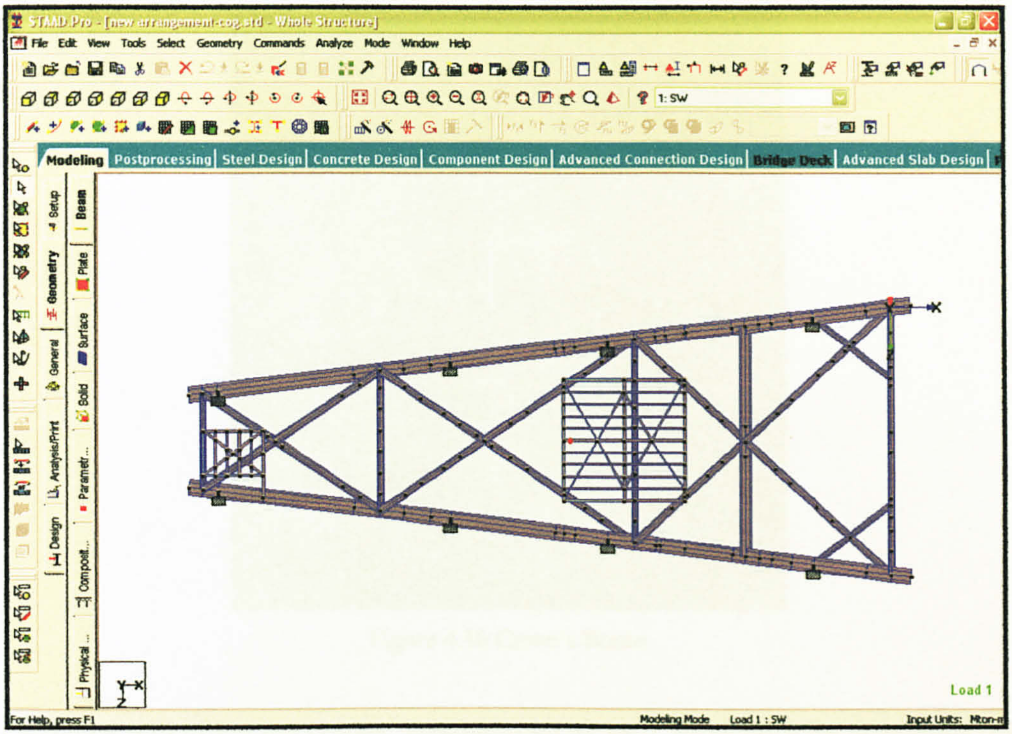


Figure 4.9 Center of Gravity

4.2.1.3 Clearance

There are two types of clearance at the site that need to be considered in the lifting design plan. Firstly is the clearance for crane's movement at site. Access planning is an important consideration in the development of an effective project-execution plan (Varghese & O'Connor, 1995). Generally, there will more than one project being fabricated at the same time at the fabrication yard, thus, the vacant area for crane's mobility is limited. Thus, it is important to know the route will be travelled by the crane/cranes.

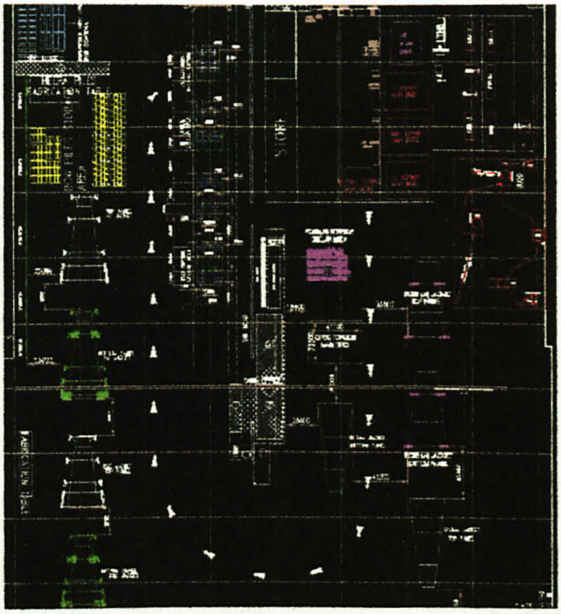


Figure 4.10 Crane's Route

The clearance will affect the cranes' arrangement as well, especially for structures that need to be upended. When a structure is being upended to its final position, the cranes that are not responsible for the final lifting should have sufficient clearance to move out from their positions. Thus proper lifting plan should be arranged to cater for this. Figure 4.9 and 4.10 are used to ease the illustration.

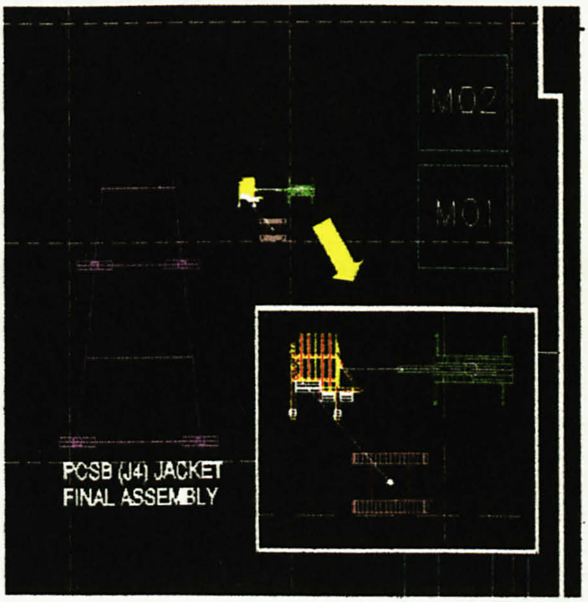


Figure 4.11 Positions of Cranes

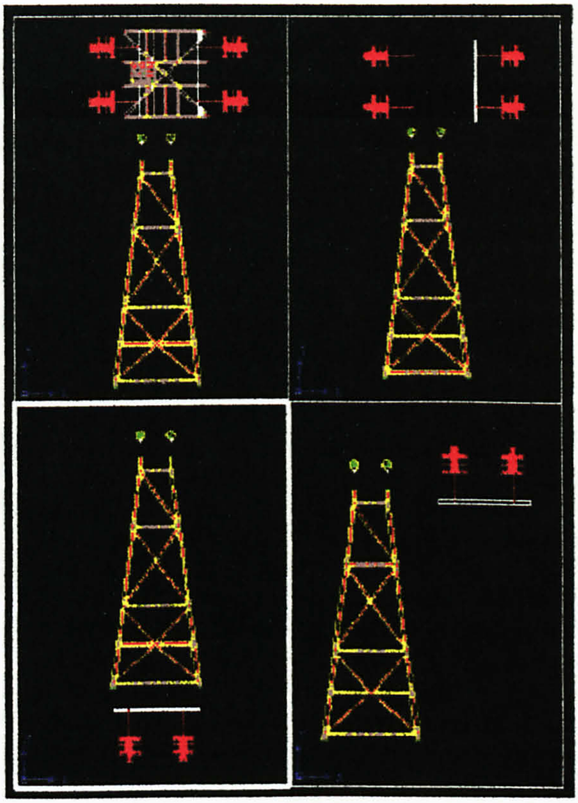


Figure 4.12 Cranes' Arrangement and Movement

Secondly is the clearance between crane's boom and the structure being lifted. Although lifting angle of 90 degrees of a crane's boom will give the maximum capacity but it is not possible to lift a structure with that lifting angle.

A lifting angle of 90 degrees will cause the side of lifted structure to come in contact with the crane's boom thus lifting is not possible. A lower lifting angle will give bigger clearance between the structure and the crane's boom but it will give a lower crane's capacity as well. And as a lifted structure being raised into the air, the higher it goes, the smaller the gap between the structure and the crane's boom will be.

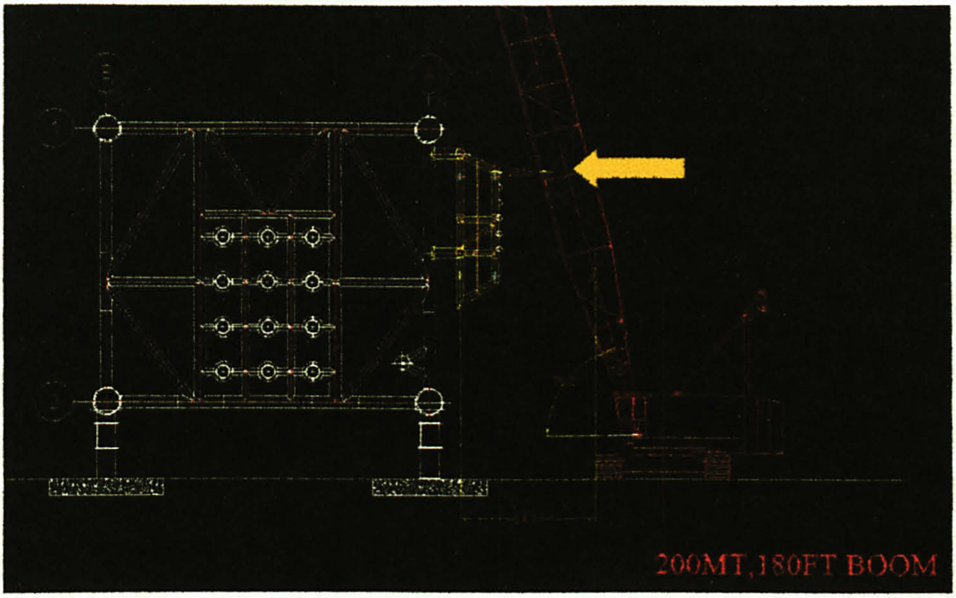


Figure 4.13 Clearance Between Structure and Boom

4.2.1.4 Crane's direction

The directionality of the crane being retracted or extended is important for the ease of crane's mobility and it will affect the crane's capacity as well. An extended crane has higher capacity than the refracted crane given the same boom length and lifting angle.

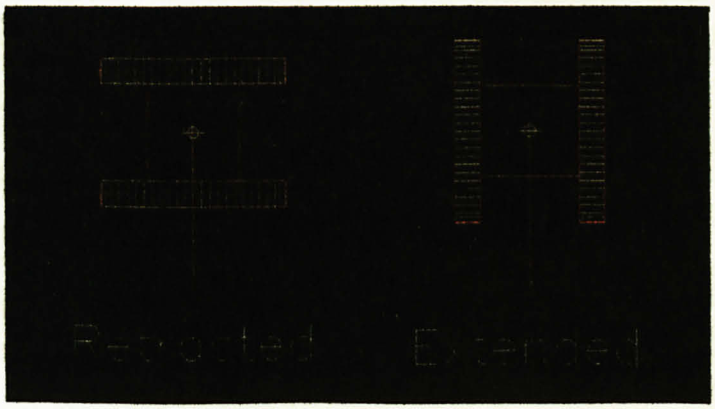


Figure 4.14 Crane's Directionality

4.2.1.5 Availability of resources (crane)

The availability of resources usually refers to the availability of cranes. Due to the costly rental or possible breakdown and maintenance of the cranes at site, this is usually the dominating factor that affects the heavy lifting design.

4.2.2 Safety Checking

There are few safe checking requirements that need to be performed to test if the lifting design is safe and fulfill both the British and American Code:

- Unity Check
- Displacement
- Deflection

4.2.2.1 Unity Check

Unity check can be obtained by analyzing the structure using AISC. Unity ratio should not exceed 1. Ratio equals to and more than 1 shows that the design is a failure. In STAAD Pro, unity ratio that is less than 1 will be shown in green, 1-1.49 in blue and more than 2 in red.

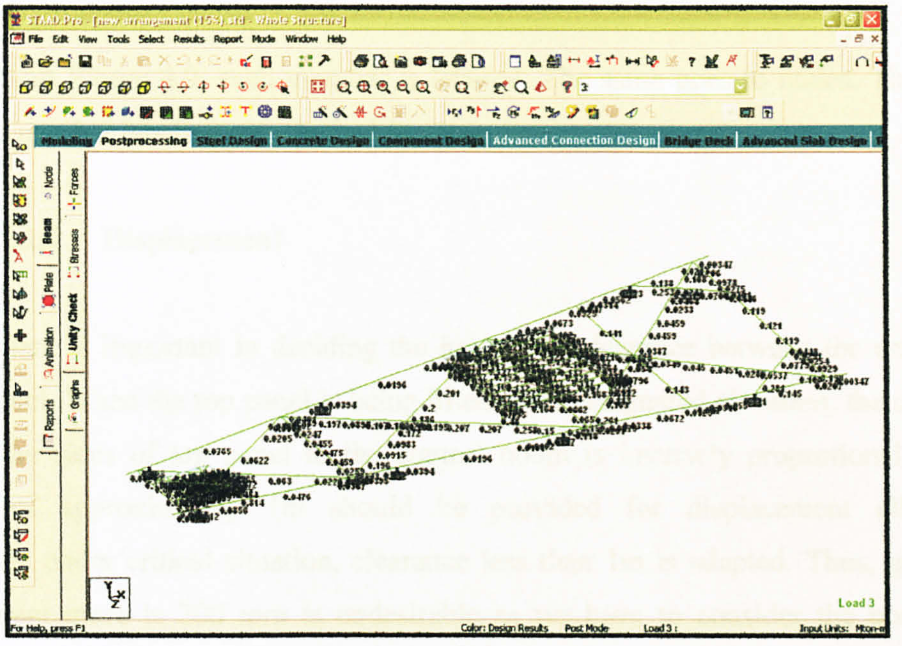


Figure 4.15 Unity Check

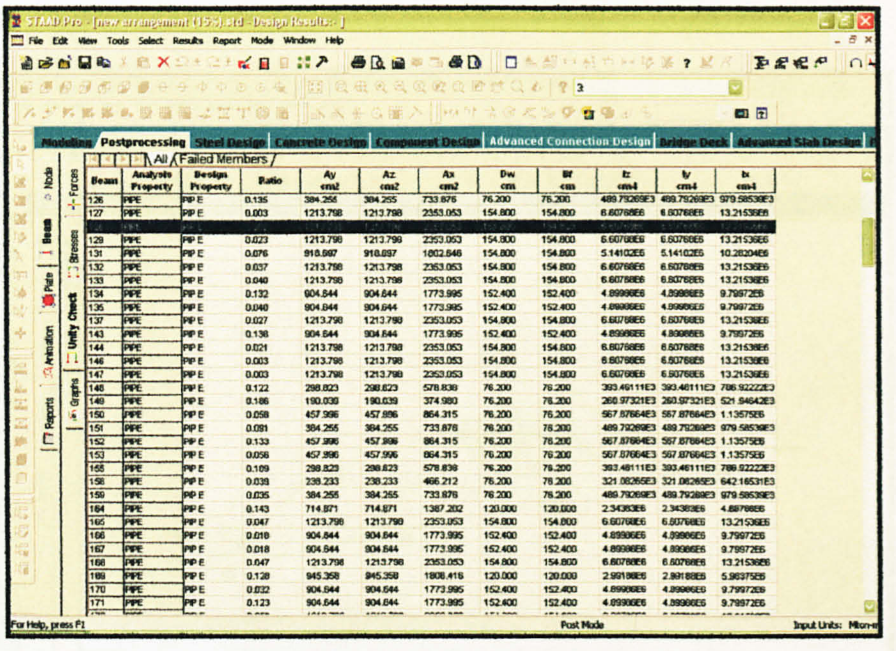


Figure 4.16 Unity Ratio in Tabular Form

For the B134-A Top Panel case study, the unity ratio ranges from as low as 0.02 to the highest of 0.889.

Thus, it can be concluded that the unity check is passed and the design is safe.

As seen from Figure 4.9, each member is labeled. The same goes to nodes. The beams and nodes number labeling are attached in appendix.

4.2.2.2 Displacement

Displacement is important in deciding the horizontal clearance between the cranes and the top panel. When the top panel is being lifted to its designated elevation, the clearance between the sides of top panel to the cranes' boom is inversely proportional. A safe distance of approximately 1m should be provided for displacement allowance. Sometimes, under critical situation, clearance less than 1m is adapted. Thus, generally, displacement more is 200 mm is undesirable as we have to consider the possible of swaying when the structure is being lifted. A higher displacement value gives higher risk of crashing between the side of the structure and the boom.

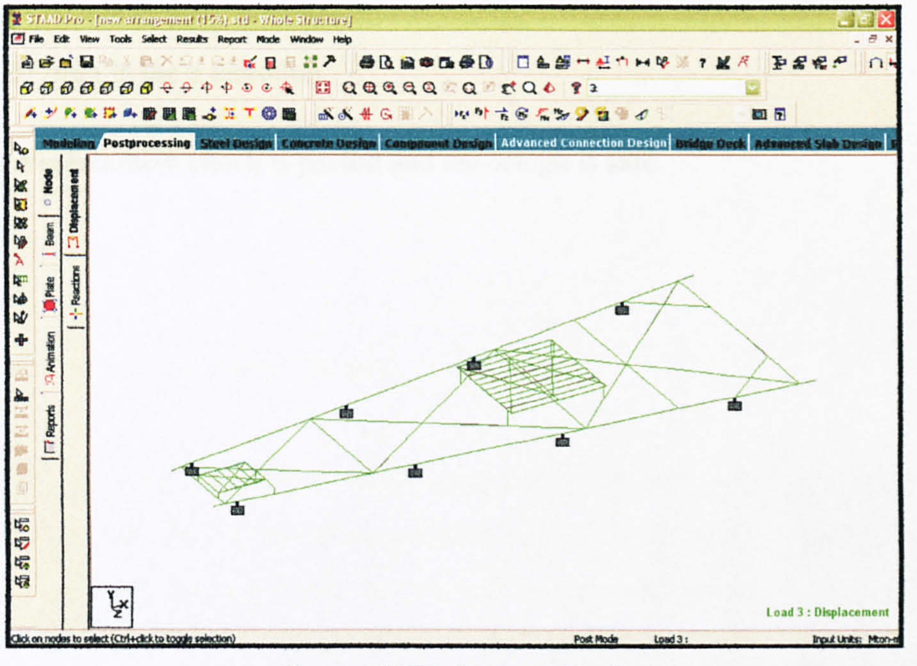
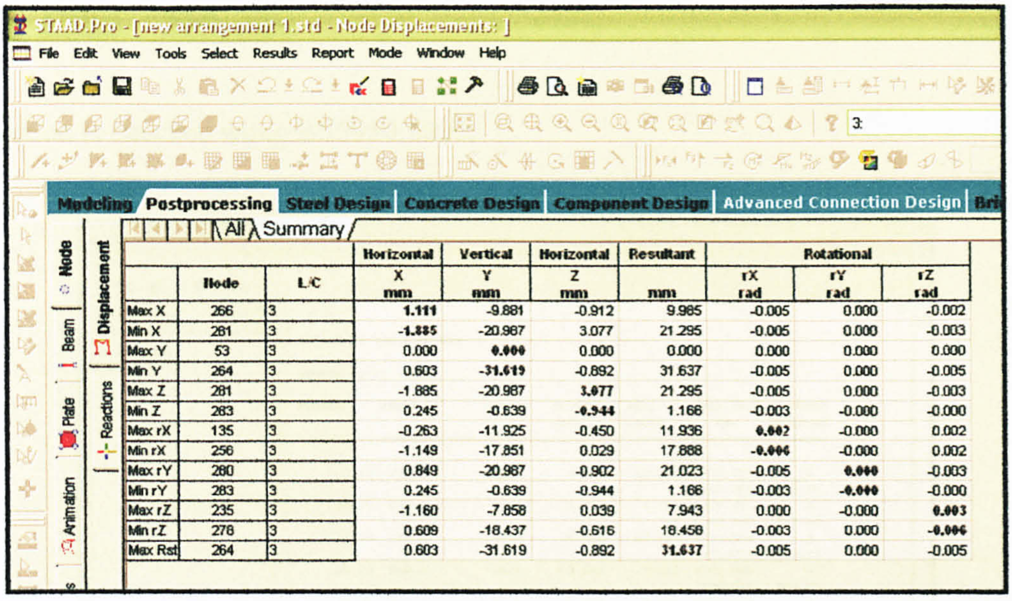


Figure 4.17 Displacement Check



	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	266	3	1.111	-9.881	-0.912	9.985	-0.005	0.000	-0.002
Min X	281	3	-1.885	-20.987	3.077	21.295	-0.005	0.000	-0.003
Max Y	53	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Min Y	264	3	0.603	-31.619	-0.892	31.637	-0.005	0.000	-0.005
Max Z	281	3	-1.885	-20.987	3.077	21.295	-0.005	0.000	-0.003
Min Z	283	3	0.245	-0.639	-0.944	1.166	-0.003	-0.000	-0.000
Max rX	135	3	-0.263	-11.925	-0.450	11.936	0.002	-0.000	0.002
Min rX	256	3	-1.149	-17.851	0.029	17.888	-0.006	-0.000	0.002
Max rY	280	3	0.849	-20.987	-0.902	21.023	-0.005	0.000	-0.003
Min rY	283	3	0.245	-0.639	-0.944	1.166	-0.003	-0.000	-0.000
Max rZ	235	3	-1.160	-7.858	0.039	7.943	0.000	-0.000	0.003
Min rZ	278	3	0.609	-18.437	-0.616	18.458	-0.003	0.000	-0.006
Max Rst	264	3	0.603	-31.619	-0.892	31.637	-0.005	0.000	-0.005

Figure 4.11 Displacement Check in Tabular Form

For this B134-A Top Panel case study, the maximum displacements are:

- 1.885 mm in the x direction
- 31.619 mm in the y direction
- 3.077mm in the z direction

Thus, the displacement check is passed and the design is safe.

4.2.2.3 Deflection

Deflection is checked using BS5950:2000.

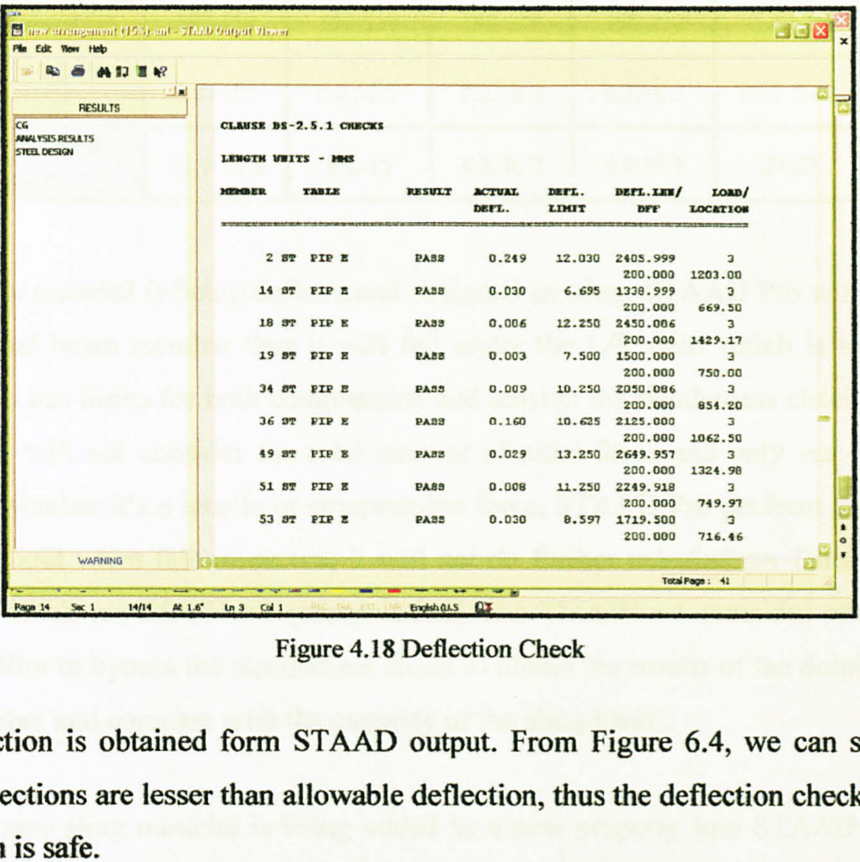


Figure 4.18 Deflection Check

The deflection is obtained form STAAD output. From Figure 6.4, we can see that all actual deflections are lesser than allowable deflection, thus the deflection check is passed. The design is safe.

4.2.3 Varying Sling Material

In order to obtain more accurate results when analyzing lifting design using different sling materials, the material specifications have to be manipulated to simulate the actual sling condition. Two methods can be used to add new material property.

Firstly, new sling can be defined through STAAD editor. Table 4.3 marks 6 types of different sling materials to be varied in the research for the simulation by manipulating Elastic Modulus, Poisson Ratio, Density and Thermal Expansion of one of the pre-defined material in STAAD Pro to give a logical estimation.

Table 4.3 Properties of Sling Material

Properties/ Materials	Carbon Steel	Alloy Steel	Stainless Steel	Tool Steel	Polyester	Nylon
Density (1000kg/m3)	7.85	7.85	7.75-8.10	7.72-8.0	1.30-1.40	1.23
Elastice Modulus (GPa)	190-210	190-210	190-210	190-210	2-4.	3.506-5.507
Poisson's ratio	0.27-0.3	0.27-0.3	0.27-0.3	0.27-0.3	0.37-0.44	0.35
Thermal Expansion (10^-6/oC)	11.0-16.6	9.0-15	9.0-20.7	9.4-15.1	20-80	52

When a new material is being defined and designed as sling, STAAD Pro will analyze it like a normal beam member thus it will fail under the L/R ratio which is slenderness. STAAD Pro has limits for both compression and tension for slenderness check following the code; it will not consider the total amount of axial force and only see the sign to determine whether it's a tensile or compressive force. STAAD Pro perform these checks by defaults and when failure occurs, it will not do further calculations Thus, two extra command which are MAIN =1 (compression) and TMAIN =1 (tension) are added in STAAD editor to bypass the slenderness check to obtain the results of the dominant force in the member and compare with the capacity of the sling itself.

Secondly, new sling material is being added as a new property into STAAD Pro using AutoCAD and STAAD Pro's Free Sketch. Figure 4.19 and 4.20 illustrates the steps taken.

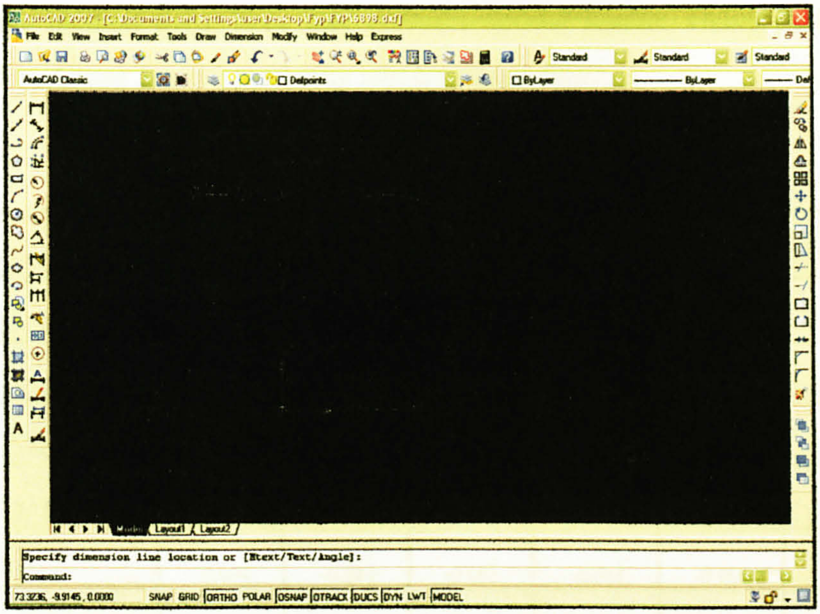


Figure 4.19 Cross Sectional

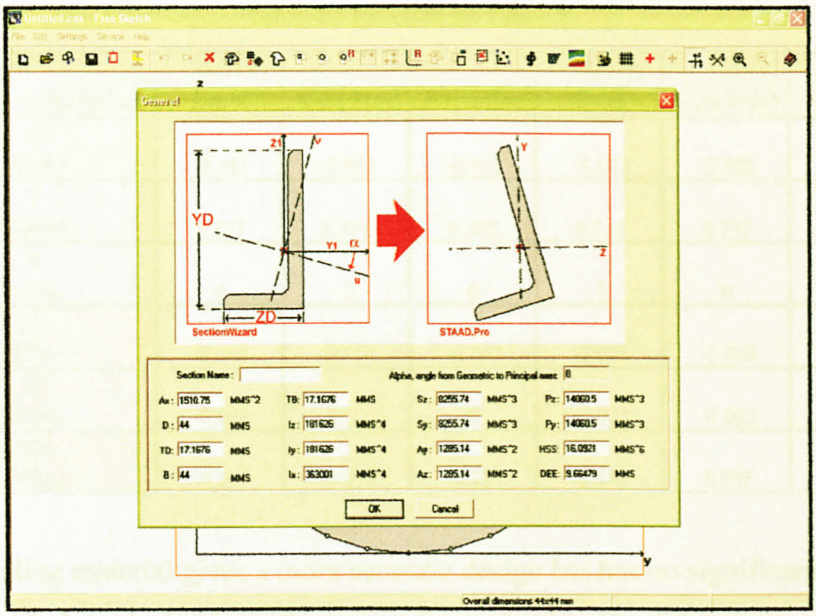


Figure 4.20 Free Sketch

The material properties generated from Free Sketch is then imported into STAAD Pro. This will give accurate material specifications to the new slings added.

Regardless the method used, both way generate similar results. Using J4 boatlanding, loads carried by Crane 1 and 2 are being tabulated as below:

Table 4.4 Reaction for Crane 1

Reactions/ Materials	Carbon Steel	Alloy Steel	Polyester	Stainless Steel	Tool Steel	Nylon
X (Mton)	0.463	0.463	0.460	0.463	0.463	0.460
Y (Mton)	12.089	12.089	11.958	12.090	12.089	11.986
Z (Mton)	0	0	0	0	0	0
Mx (kNm)	0.007	0.007	0.001	0.007	0.007	0
My (kNm)	-0.004	-0.004	-0.001	-0.004	-0.004	0
Mz (kNm)	10.032	10.032	9.955	10.033	10.033	9.954

Table 4.5 Reaction for Crane 2

Reactions/ Materials	Carbon Steel	Alloy Steel	Polyester	Stainless Steel	Tool Steel	Nylon
X (Mton)	-0.463	-0.463	-0.460	-0.463	-0.463	-0.460
Y (Mton)	8.717	8.717	8.588	8.718	8.717	8.585
Z (Mton)	0	0	0	0	0	0
Mx (kNm)	-0.008	-0.008	-0.001	-0.008	-0.008	0
My (kNm)	-0.003	-0.003	0	-0.003	-0.003	0
Mz (kNm)	-6.917	-6.917	-6.817	6.918	6.917	6.816

Varying the sling material gives a more accurate design but has no significant effect on heavy structures because load reactions vary due to the density of the sling.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

There are many causes that lead to lifting dangerous occurrences such as mechanical failure, crane operator's negligence, poor rigging/lifting arrangement, poor lift planning and lack of supervision and rigging competency. This project tackles poor lift planning. The main issues to be considered in lifting are the weight of structure, center of gravity clearance, crane's direction and availability of resources. The dominating issue of affecting the lifting design plan is the availability of the cranes which directly affect the cost.

5.2 Recommendation

Further research can be done on developing a computerized heavy lift planning system for planning crane lifts.

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APPENDICES

B134-A Top Panel

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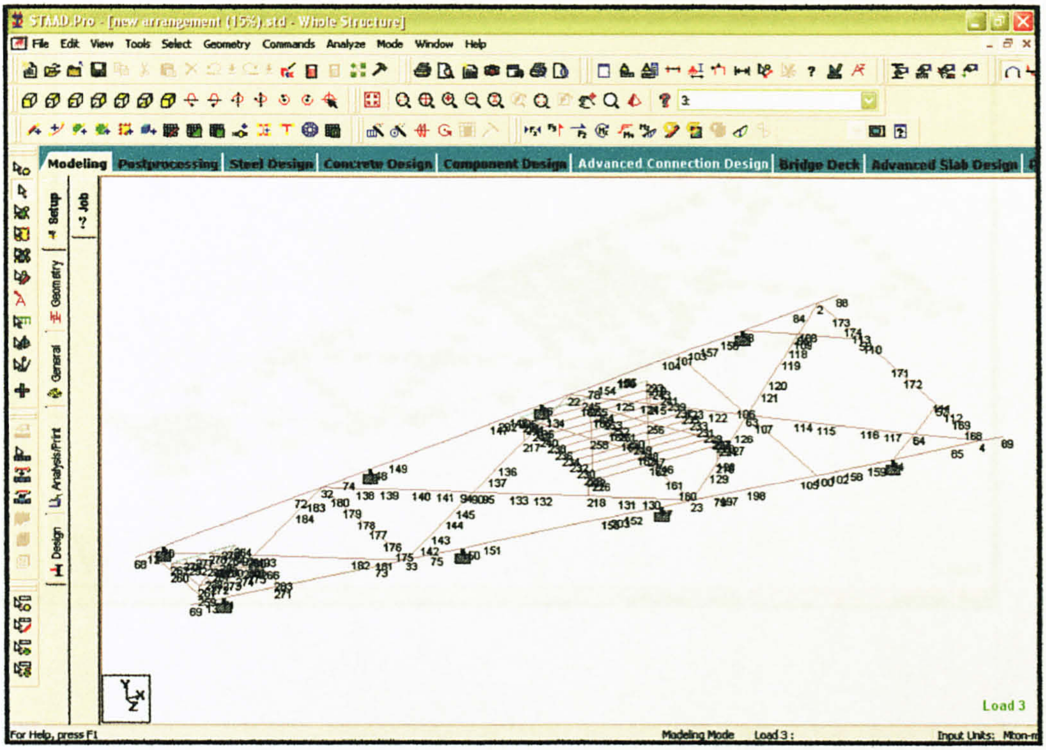

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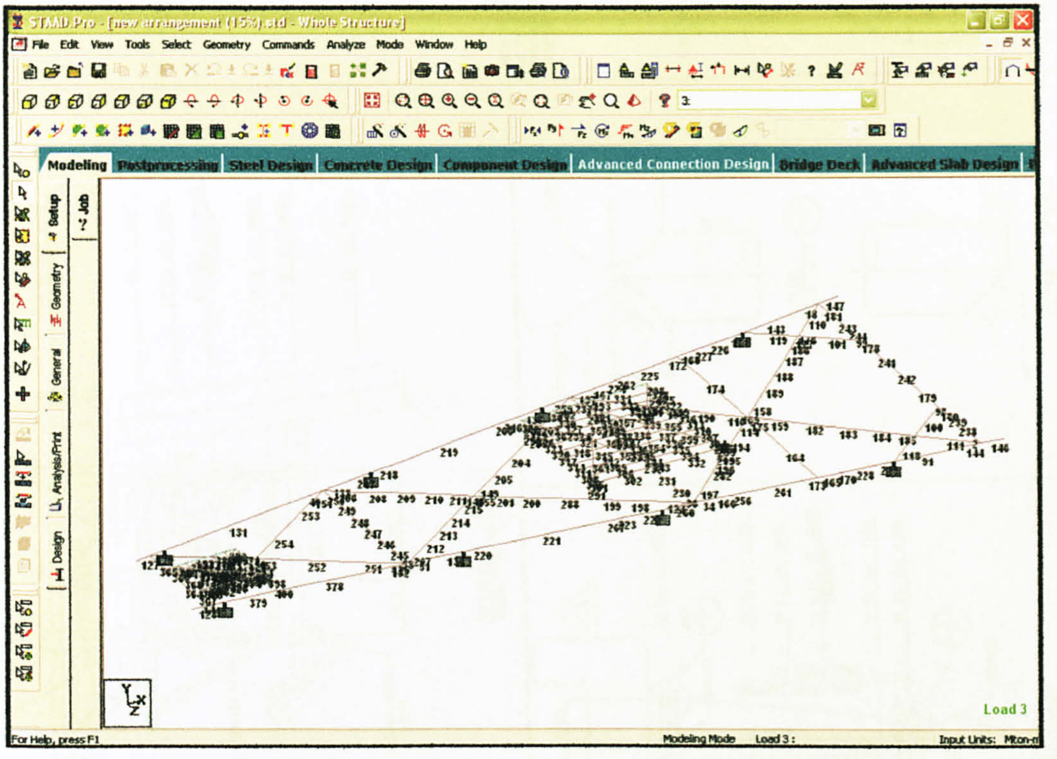

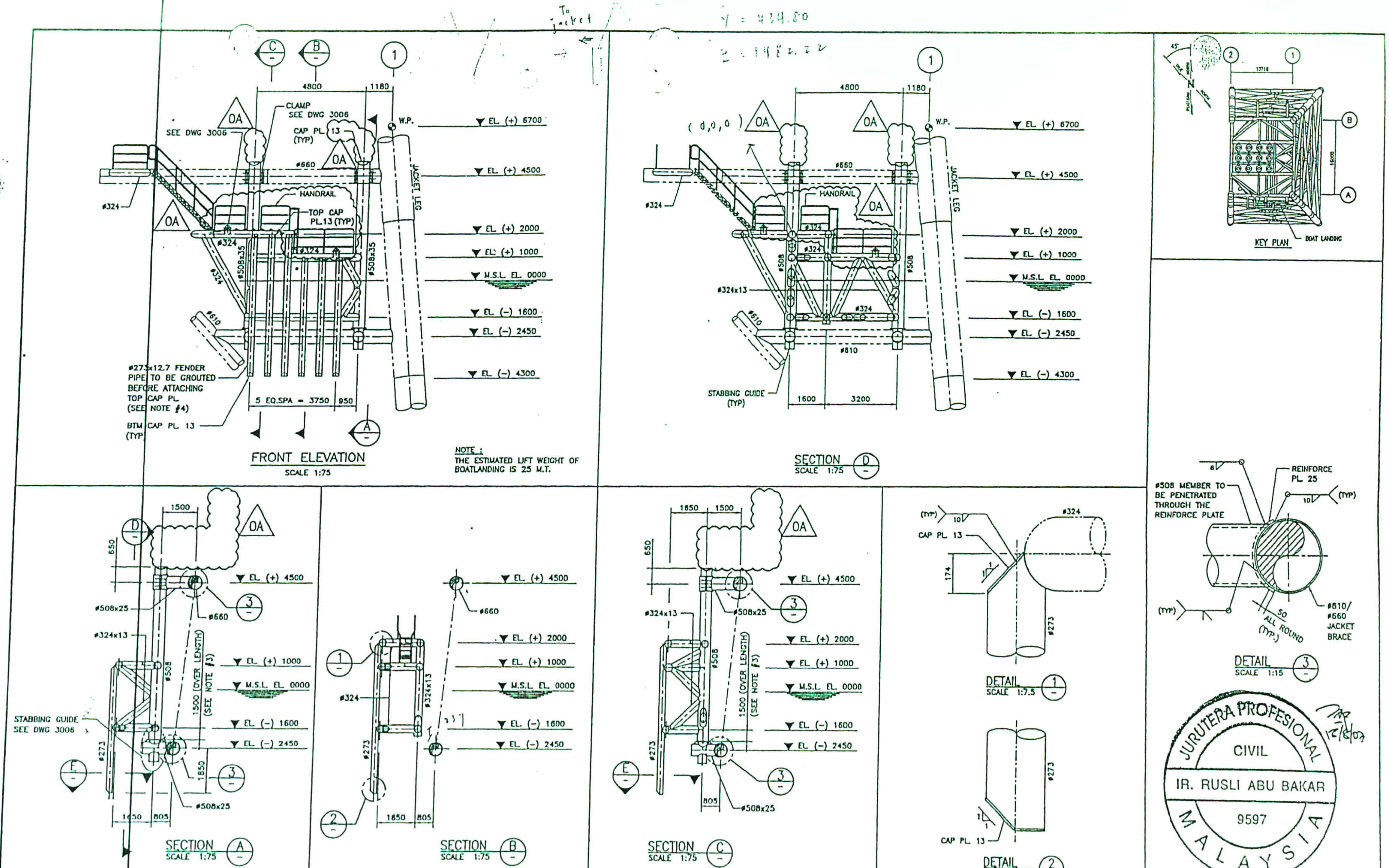

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4. GROUT MIXTURE TO BE PREPARED FROM API CLASS 'A' CEMENT BLEND WITH 2% CALCIUM CHLORIDE & MIXED WITH FRESH WATER. MIXTURE SHOULD CONSIST OF 45 PARTS WATER TO 100 PARTS CEMENT BY WEIGHT TO YIELD MIN. 28 DAYS EST. COMPRESSIVE STRENGTH OF 3000 PSI.

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DETAILED DESIGN ENGINEERING SERVICES FOR EPCC OF J4 DEVELOPMENT

DRAWINGS TITLE

JACKET
BOATLANDING
ELEVATIONS AND SECTIONS

CONSULTANT: MMC Oil & Gas Engineering Sdn Bhd — MMC
EPC CONTRACTOR: KENCANA HL SDN BHD — Kencana HL

PETRONAS CARIGALI SDN BHD (30275-U)

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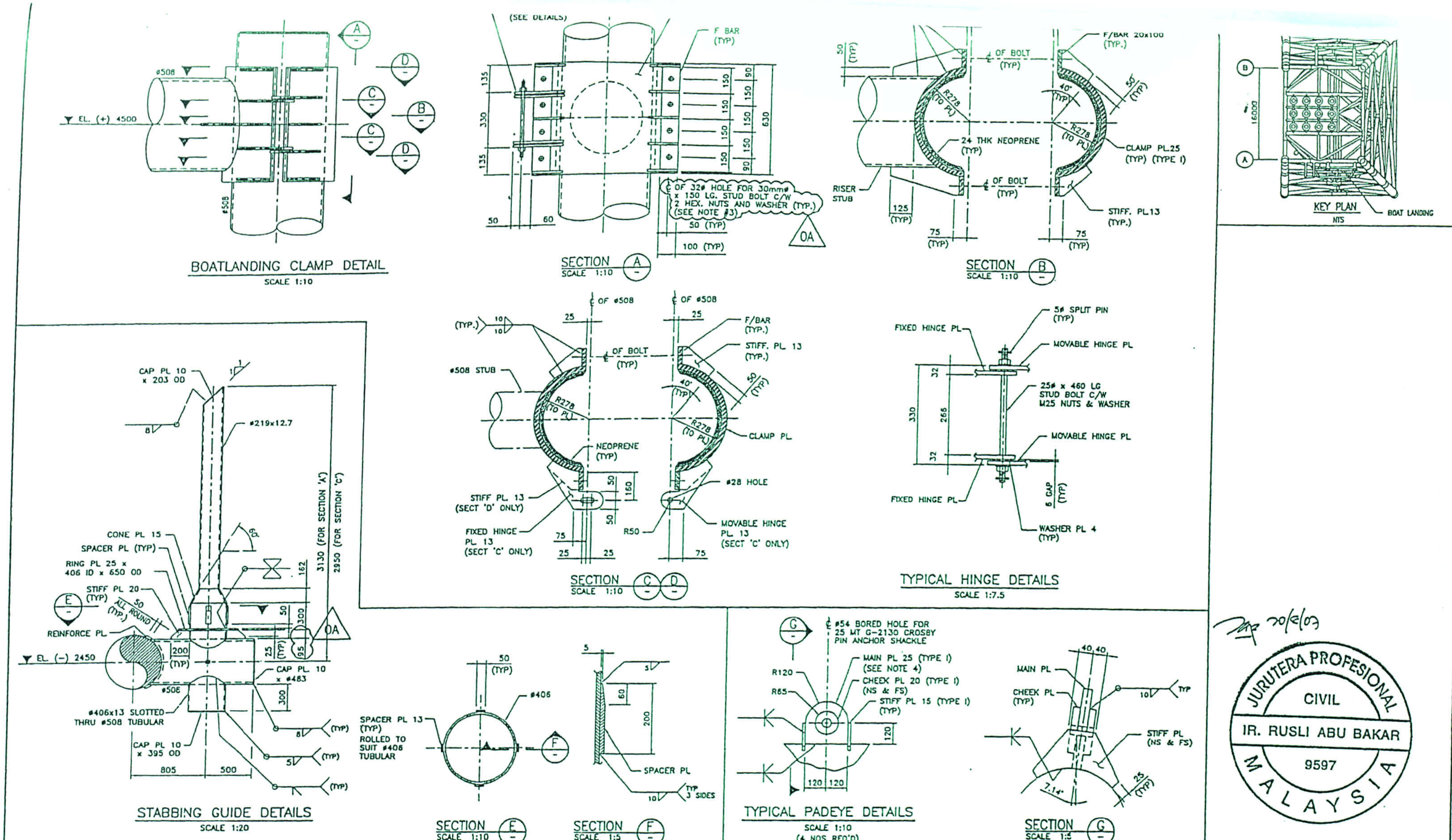

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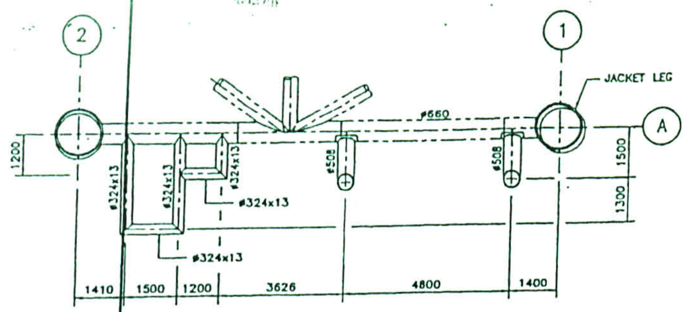

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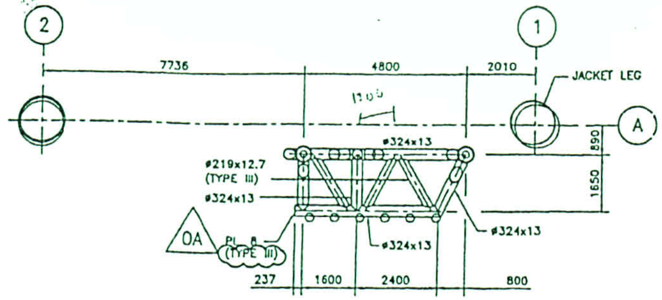

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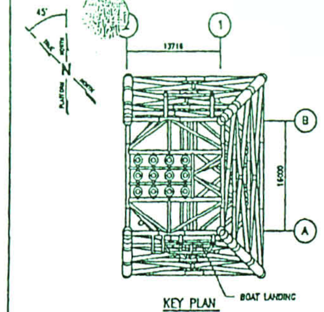

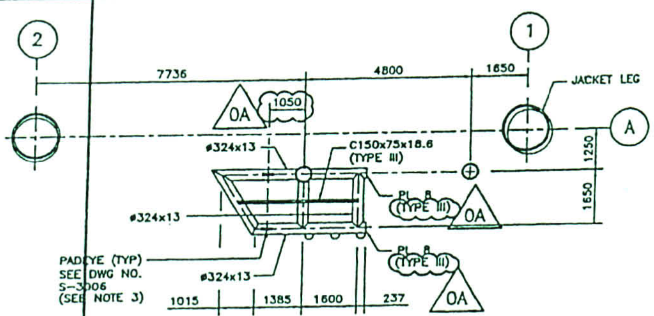

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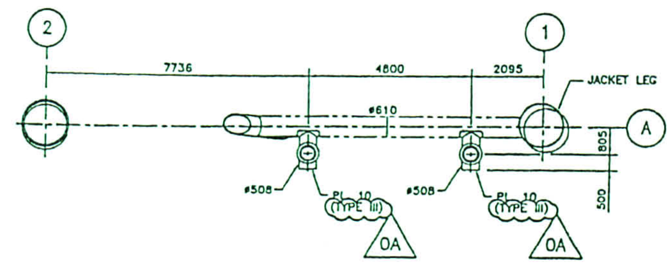

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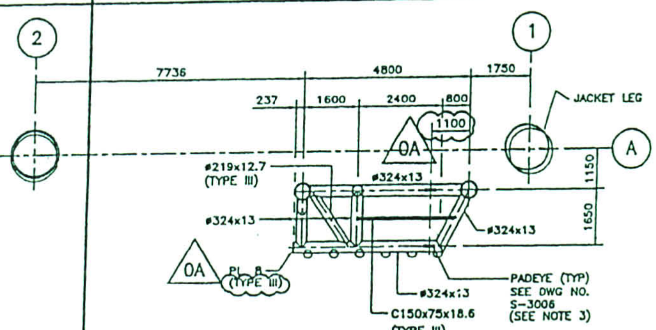

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